Providing Safe Schools for Our Students

by

Timothy J. Walsh

Washington Department of Natural Resources

Division of Geology and Earth Resources

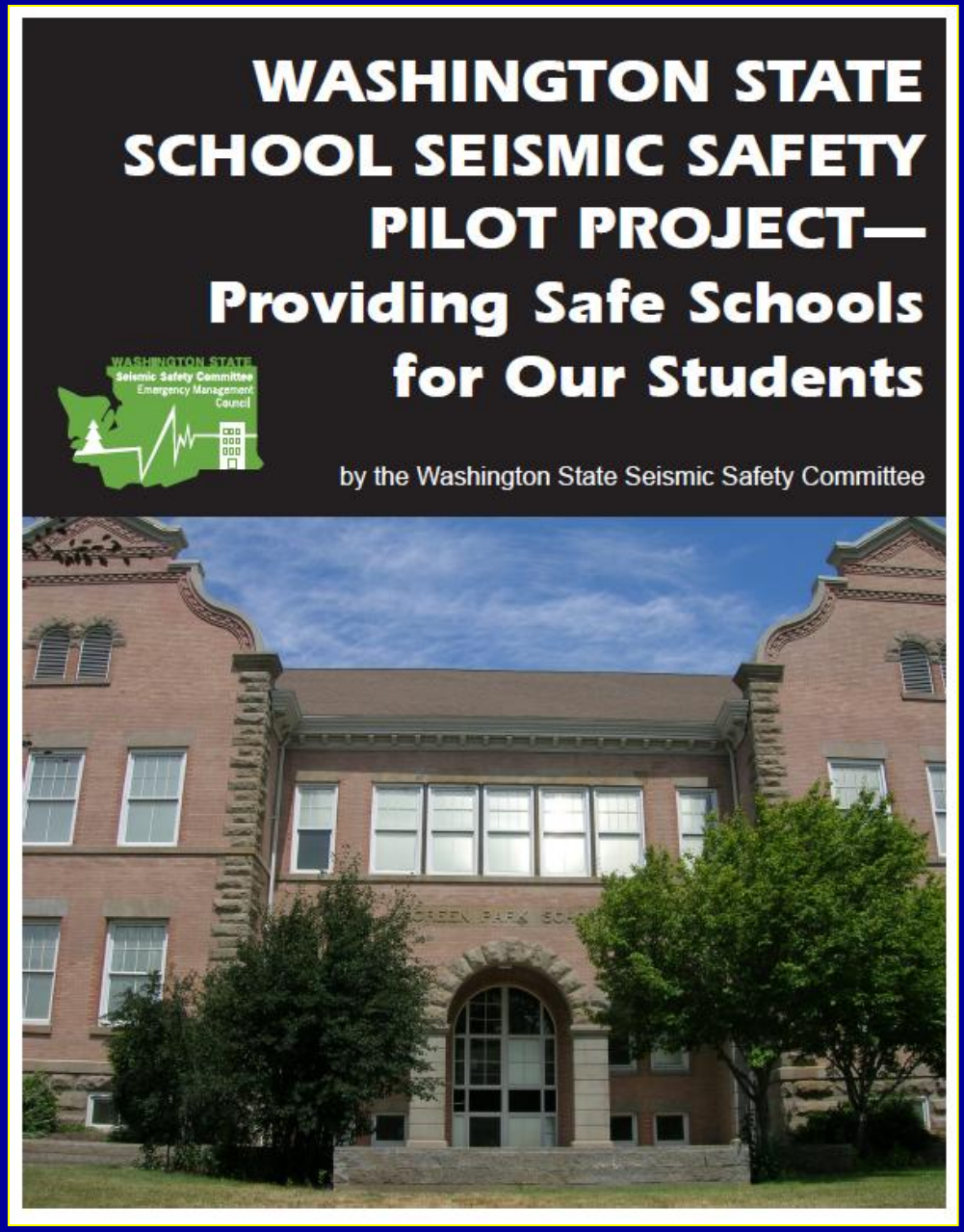
October 25, 2011

WASHINGTON STATE DEPARTMENT OF Natural Resources

WASHINGTON STATE Seismic Safety Committee Emergency Management Council

"**Children have the right to be safe in school buildings during earthquakes**"

-Western States Seismic Policy Council



Washington Military Department
Emergency Management Division

STRUCTURAL ENGINEERS ASSOCIATION SEA WASHINGTON

WASHINGTON STATE
Seismic Safety Committee
Emergency Management Council

OSPI
Superintendent of Public Instruction

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark • Commissioner of Public Lands

Why Assess School Buildings?

- Do YOU know how many schools in Washington State are vulnerable to extensive damage or even collapse in an earthquake?
- Do YOU know how many kids are at risk in these buildings?
- Do YOU know which school districts have retrofitted some or all their buildings?
- **You might be surprised to know that neither does anyone else…**
- With a critical shortfall of already scarce financial resources (e.g.. Trust lands funding) available to build or retrofit, how can state & local decision makers best prioritize actions and know where to put these resources?

Washington Schools have been Damaged in Earthquakes

1949, a large earthquake collapsed the gymnasium roof at Puyallup High School. The earthquake occurred at 11:58 a.m., and the gym had just been vacated by workers for lunch.

At Castle Rock High School, however, falling masonry killed the student body president as he tried to escape from the building.

Another student was killed by falling bricks at Lowell Grammar School in Tacoma

In all, thirty schools were damaged in this Nisqually-type earthquake

Figure 2. At Castle Rock, a high school student was killed as unanchored gable masonry cascaded to the walk outside the entrance. There could have been more casualties. (From Edwards, 1951.)

Figure 1. Open air theatre—Three members of the stage crew at Puyallup High School survey the wreckage of the stage, which was saved in by the earthquake just as they were leaving for lunch. Under the debris are a ping-pong table and a grand piano. *Seattle Times* staff photo by Larry Dion (from Ulrich, 1949).

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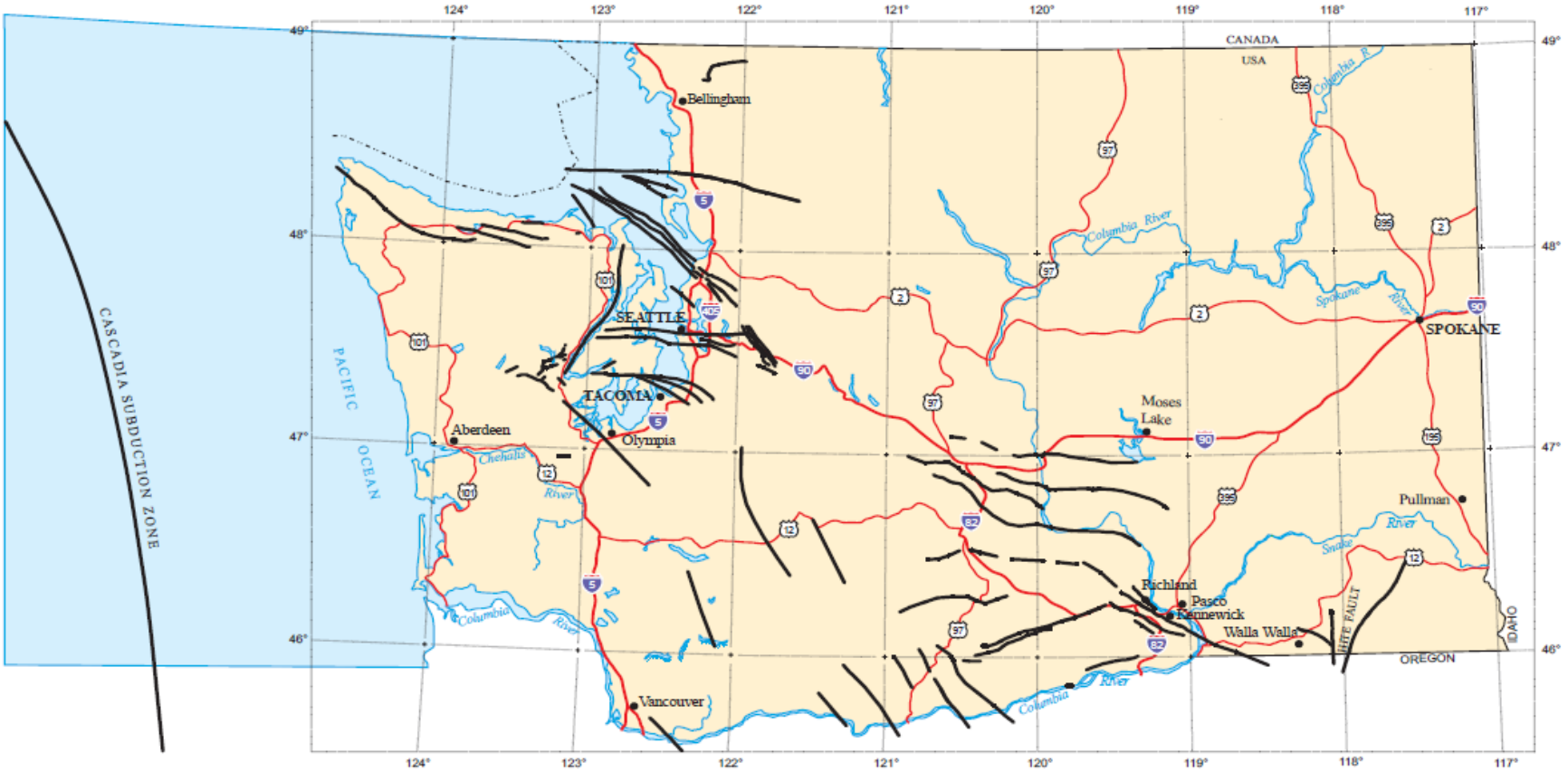

Figure 3. Simplified map of known and suspected active faults (heavy black lines) affecting earthquake hazard in Washington. It includes faults that have been demonstrated to have caused earthquakes since the last ice age but also faults that are under investigation.

What are the sources of earthquakes in Washington? Here are the active and suspected a active faults in Washington

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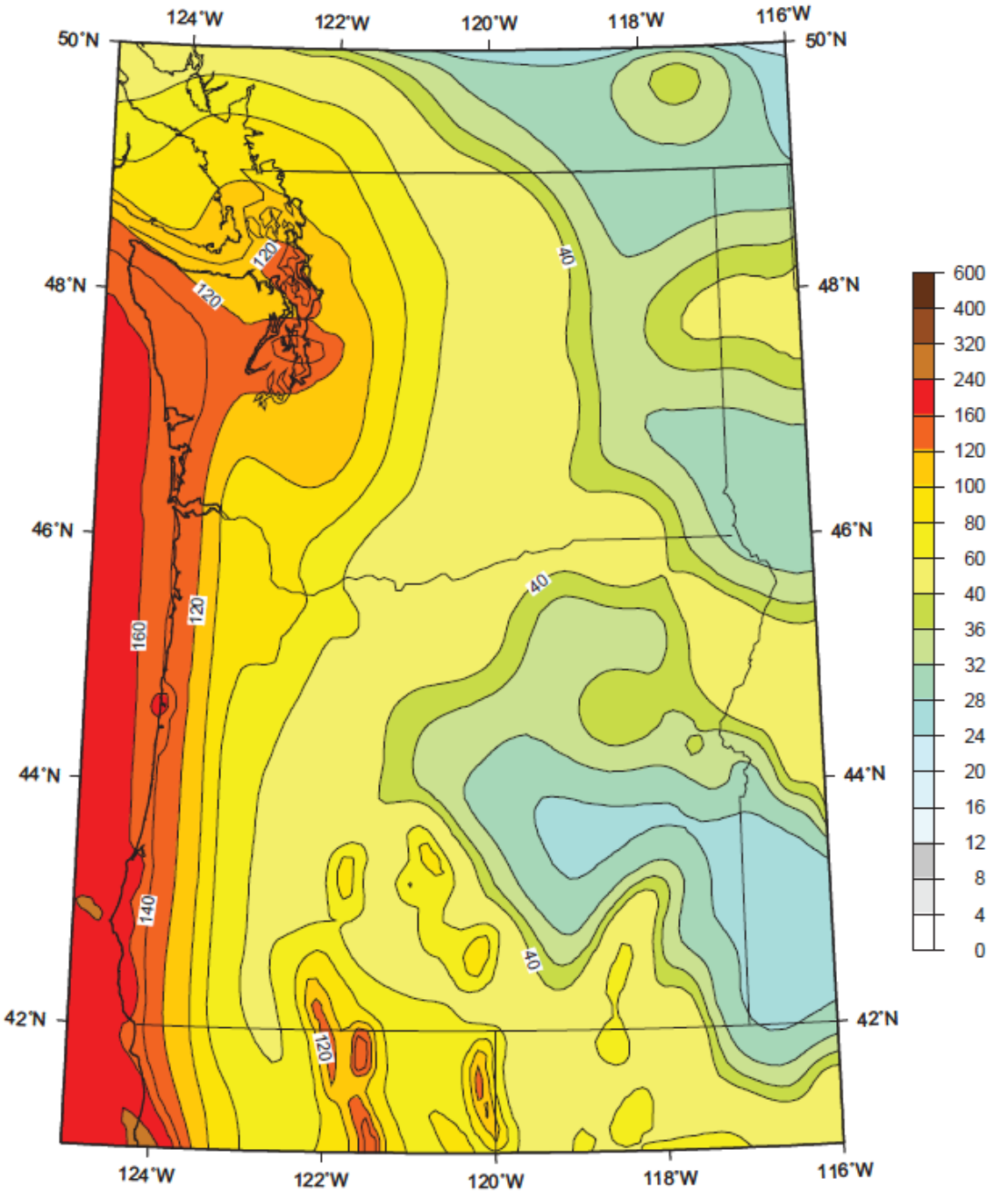
Probabilistic seismic hazard map for the Pacific Northwest. This is the basis of the 2009 International Building Code



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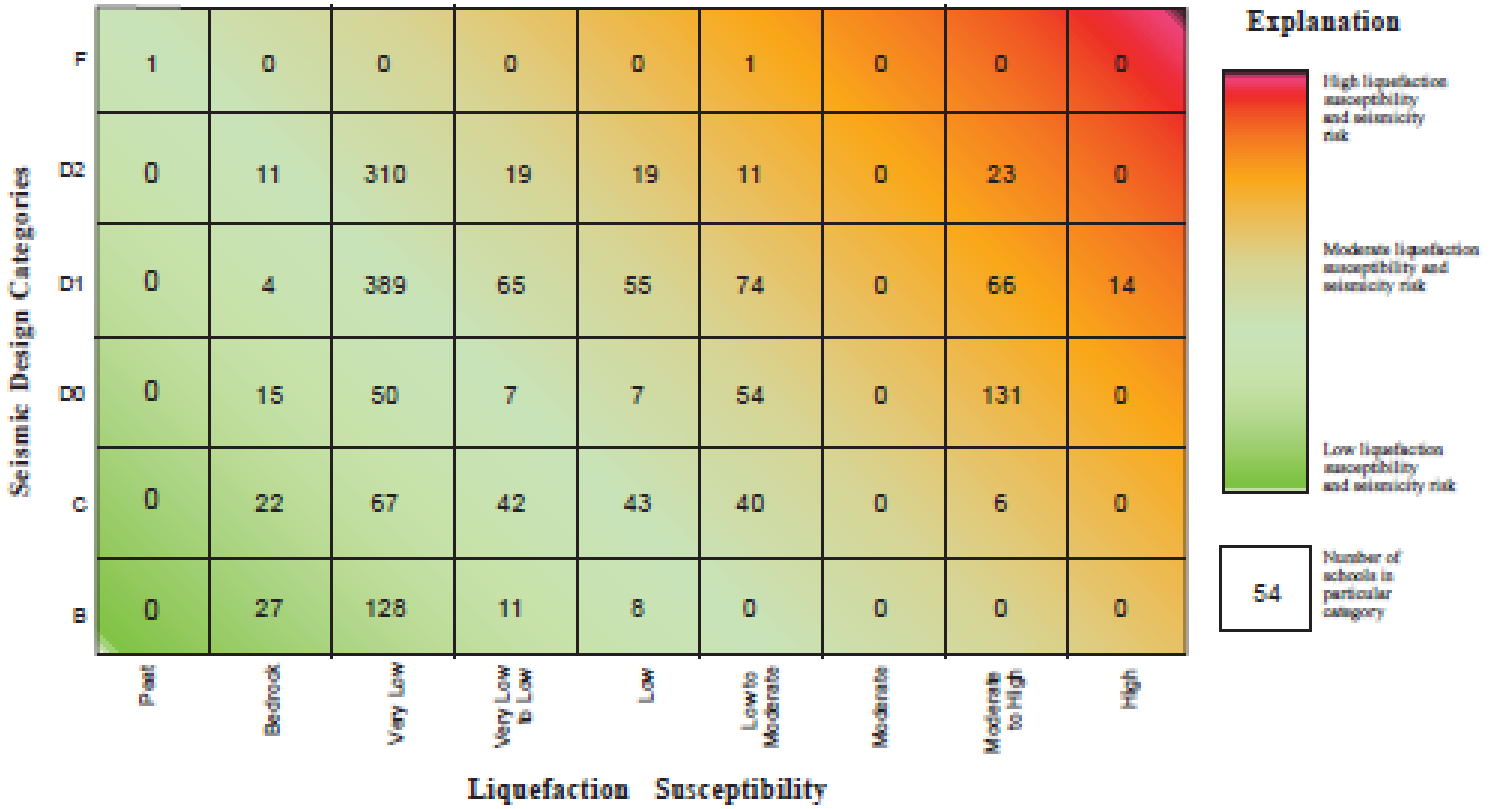
Selection Process

1) Our initial screening was to consider school districts that had high earthquake hazard. We mapped schools on a combination of the seismic design category map and liquefaction susceptibility maps.

2) School districts in both eastern and western Washington that scored high in criterion 1 were plotted.

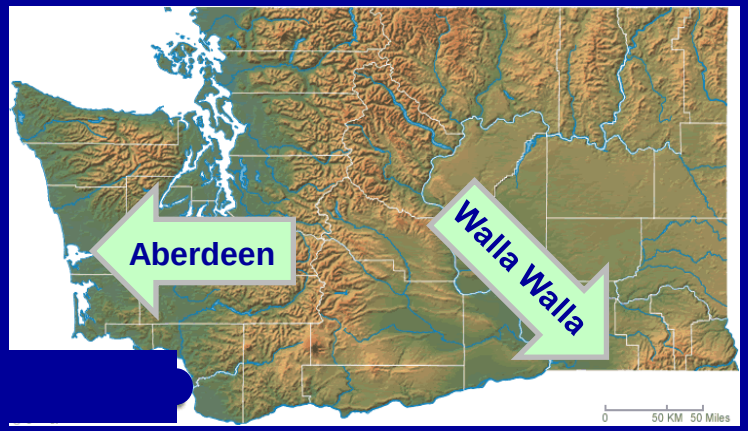
3) The number of schools per district were considered, both to equalize each district and to select a number of school buildings that could be evaluated with the available resources.

4) A representative of the Office of the Superintendent of Public Instruction then contacted a select number of school districts to determine their willingness to participate.

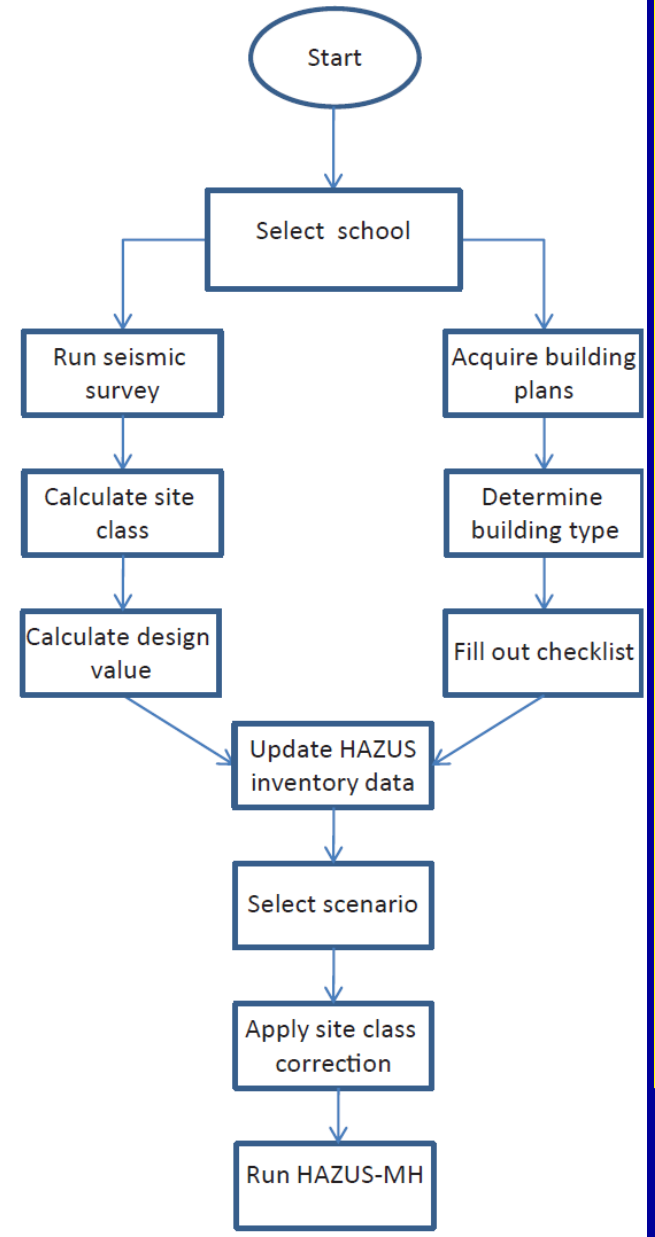


Note: The seismic design category combines an estimate of the strength of ground shaking at any individual site with the amplification caused by the local geology.

School Seismic Needs Assessment



- Pilot Project in the Cities of Walla Walla and Aberdeen
- Leverage volunteer expertise from Structural Engineering Association of Washington (SEAW) to investigate structural issues and Washington Association of Building Officials (WABO) to evaluate non-structural issues.
- Project used ASCE 31: Evaluation of Existing Buildings for structural assessment, VS-30 data for local geology assessment, and HAZUS for modeling of potential losses using 2 different scenarios.
- Intent was to develop a method that can be used statewide to assess all school buildings for seismic safety.



Screening Process

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Aberdeen administration building

Building Name: Administration Building Date: 11/15/10

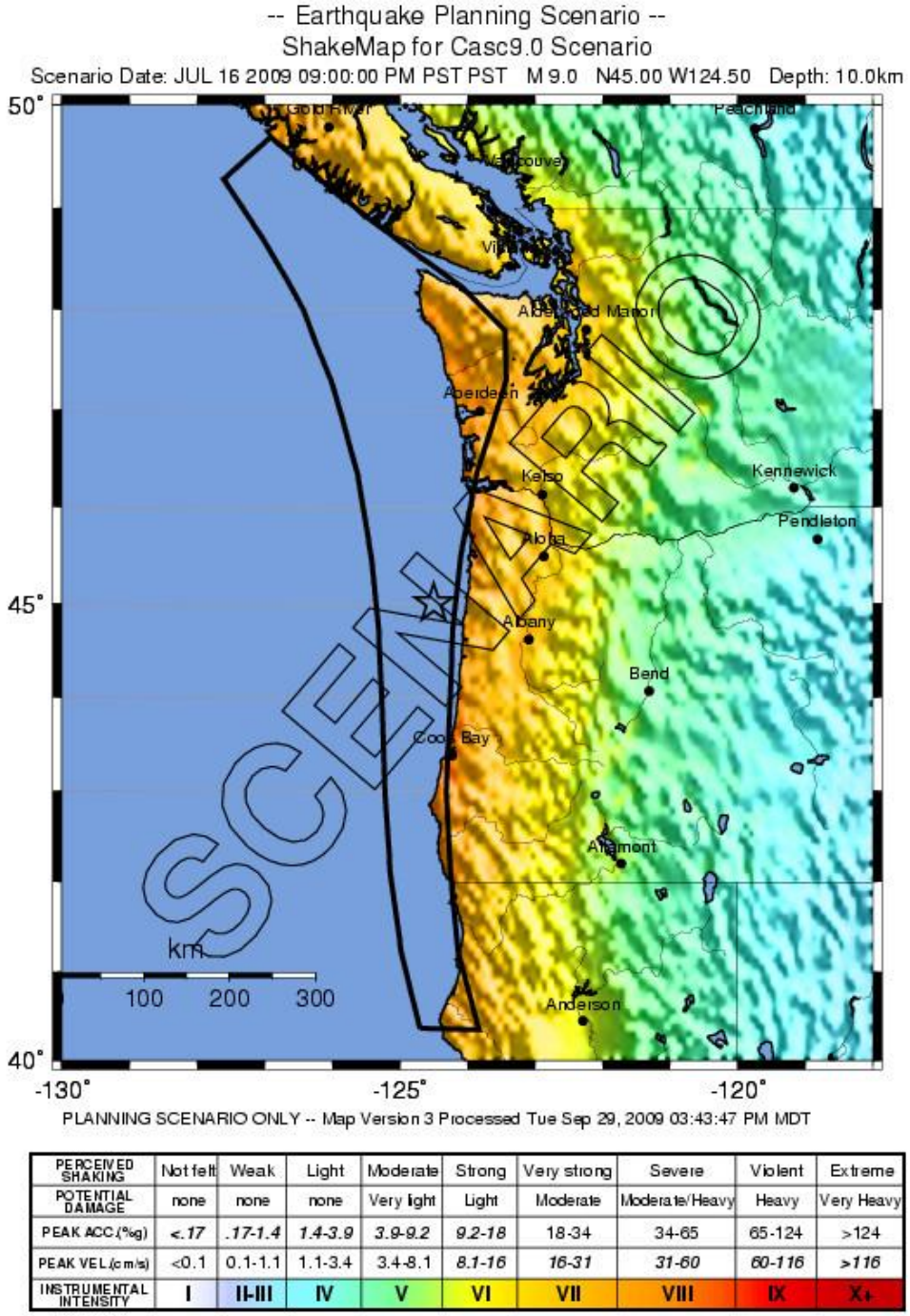
Building Address: 216 N 'G' Street, Aberdeen, WA 98520 Page: 1 of

Job Number: Job Name: By: MEB Checked:

ASCE 31 BASIC CHECKLIST URMA: UNREINFORCED MASONRY BEARING WALL BUILDINGS WITH RIGID OR STIFF DIAPHRAGMS

C	NC	N/A			Comments
			BUILDING SYSTEM		
☒	☐	☐	4.3.1.1	LOAD PATH: The structure shall contain a minimum of one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation.	Diaphragms-to-walls; walls-to-foundation.
☒	☐	☐	4.3.1.3	MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure.	Mezzanine attached to main LFRS.
☐	☒	☐	4.3.2.1	WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story, above or below, for Life-Safety and Immediate Occupancy.	Top Flr, N-S Direction, Approx 66% of 1st Flr
☐	☒	☐	4.3.2.2	SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the lateral-force-resisting system stiffness in an adjacent story above or below, or less than 80% of the average lateral-force-resisting system stiffness of the three stories above or below for Life Safety and Immediate Occupancy.	1st Flr, E-W Direction, Approx 44% of Top Flr
☐	☒	☐	4.3.2.3	GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses and mezzanines.	Lower portion of building is > 30% length of upper portion.
☒	☐	☐	4.3.2.4	VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation.	All vertical elements continuous to foundation.
☐	☒	☐	4.3.2.5	MASS: There shall be no change in effective mass of more than 50% from one story to the next for Life Safety and Immediate Occupancy. Light roofs, penthouses and mezzanines need not be considered.	Roof Approx 30% Wt of combined 2nd Flr/Lower Bldg Roof.
☒	☐	☐	4.3.2.6	TORSION: The estimated distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy.	
☒	☐	☐	4.3.3.4	DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements.	No significant deterioration observed.
☒	☐	☐	4.3.3.7	MASONRY UNITS: There shall be no visible deterioration of masonry units.	No significant deterioration observed.
☒	☐	☐	4.3.3.8	MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar.	Mortar was sound.

Scenario Magnitude 9.0 earthquake on the Cascadia subduction zone (from Art Frankel)



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

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Damage state		Description
	Slight	Small plaster cracks at comers of door and window openings and wall–ceiling intersections; small cracks in masonry chinmeys and masonry veneers. Small cracks are assumed to be visible with a maximum width of less than 1/8 inch (cracks wider than 1/8 inch are referred to as “large” cracks).
	Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear-wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
	Extensive	Large diagonal cracks across shear-wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations.
	Complete	Structure may have large permanent lateral displacement or be in imminent danger of collapse due to cripple-wall failure or failure of the lateral-load-resisting system; some structures may slip and fall off the foundation; large foundation cracks. Three percent of the total area of buildings with Complete damage is expected to be collapsed, on average.

Examples of damage states estimated by Hazus

Aberdeen, Building Code Value

Name	None	Slight	Moderate	Extensive	Complete	At Least Extensive
A J WEST ELEMENTARY	15%	56%	28%	1%	0%	1%
ABERDEEN S DIST ADMIN BLD	0%	0%	0%	2%	98%	100%
ALEXANDER YOUNG ELEM	0%	0%	0%	8%	92%	100%
CENTRAL PARK ELEMENTARY	0%	1%	28%	54%	17%	72%
HARBOR HIGH SCHOOL	0%	0%	0%	8%	92%	100%
HOPKINS ELEMENTARY	0%	0%	0%	8%	92%	100%
J M WEATHERWAX - ABERDEEN HS	41%	45%	13%	0%	0%	0%
MCDERMOTH ELEMENTARY	45%	42%	13%	0%	0%	0%
MILLER JUNIOR HIGH	0%	0%	5%	42%	53%	95%
ROBERT GRAY ELEMENTARY	54%	41%	5%	0%	0%	0%
SAM BENN GYM (ABERDEEN HS)	34%	54%	12%	0%	0%	0%
STEVENS ELEMENTARY SCHOOL	0%	0%	5%	42%	53%	95%
STEWART BLD - ROBERT GRAY ELM	0%	0%	3%	32%	66%	97%

Aberdeen, M9.0 scenario

Name	None	Slight	Moderate	Extensive	Complete	At Least Extensive
SAM BENN GYM (ABERDEEN HS)	4%	40%	53%	4%	0%	4%
STEWART BUILDING (Robert Gray)	0%	1%	17%	56%	26%	82%
ROBERT GRAY ELEMENTARY	2%	34%	58%	6%	0%	6%
A J WEST ELEMENTARY	4%	40%	53%	4%	0%	4%
ALEXANDER YOUNG ELEMENTARY	0%	1%	24%	56%	18%	74%
ABERDEEN S. DIST ADMIN BLD.	0%	1%	10%	38%	51%	90%
CENTRAL PARK ELEMENTARY	1%	22%	67%	10%	0%	10%
HARBOR HIGH SCHOOL	0%	1%	24%	56%	18%	74%
HOPKINS ELEMENTARY	0%	1%	24%	56%	18%	74%
J M WEATHERWAX (ABERDEEN) HS	13%	44%	41%	2%	0%	2%
MCDERMOTH ELEMENTARY	2%	20%	59%	19%	0%	19%
MILLER JUNIOR HIGH	0%	9%	65%	24%	2%	26%
STEVENS ELEMENTARY SCHOOL	0%	9%	65%	24%	2%	26%

Green Park Elementary

Building Name: Green Park Elementary – Original Building Date: _____

Building Address: _____ Page: 1 of 2

Job Number: _____ Job Name: _____ By: DRW Checked: _____

ASCE 31 BASIC CHECKLIST URM: UNREINFORCED MASONRY BEARING WALL BUILDINGS WITH FLEXIBLE DIAPHRAGMS

C	NC	N/A			Comments
			BUILDING SYSTEM		
☒	☐	☐	4.3.1.1	LOAD PATH: The structure shall contain a minimum of one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation.	
☐	☒	☐	4.3.1.2	ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building shall be greater than 4% of the height of the shorter building for Life Safety and Immediate Occupancy.	**2" seismic joint provided. Attic is 44.5 ft AFF, requiring a 21" seismic separation.**
☐	☐	☒	4.3.1.3	MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure.	
☒	☐	☐	4.3.2.1	WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story, above or below, for Life-Safety and Immediate Occupancy.	
☒	☐	☐	4.3.2.2	SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the lateral-force-resisting system stiffness in an adjacent story above or below, or less than 80% of the average lateral-force-resisting system stiffness of the three stories above or below for Life Safety and Immediate Occupancy.	
☒	☐	☐	4.3.2.3	GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses and mezzanines.	
☒	☐	☐	4.3.2.4	VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation.	
☒	☐	☐	4.3.2.5	MASS: There shall be no change in effective mass of more than 50% from one story to the next for Life Safety and Immediate Occupancy. Light roofs, penthouses and mezzanines need not be considered.	
☒	☐	☐	4.3.3.1	DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal connection hardware shall be deteriorated, broken, or loose.	
☒	☐	☐	4.3.3.7	MASONRY UNITS: There shall be no visible deterioration of masonry units.	
☒	☐	☐	4.3.3.8	MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar.	**Limited assessment made of joints.**

Building Name: Green Park Elementary – Original Building Date:

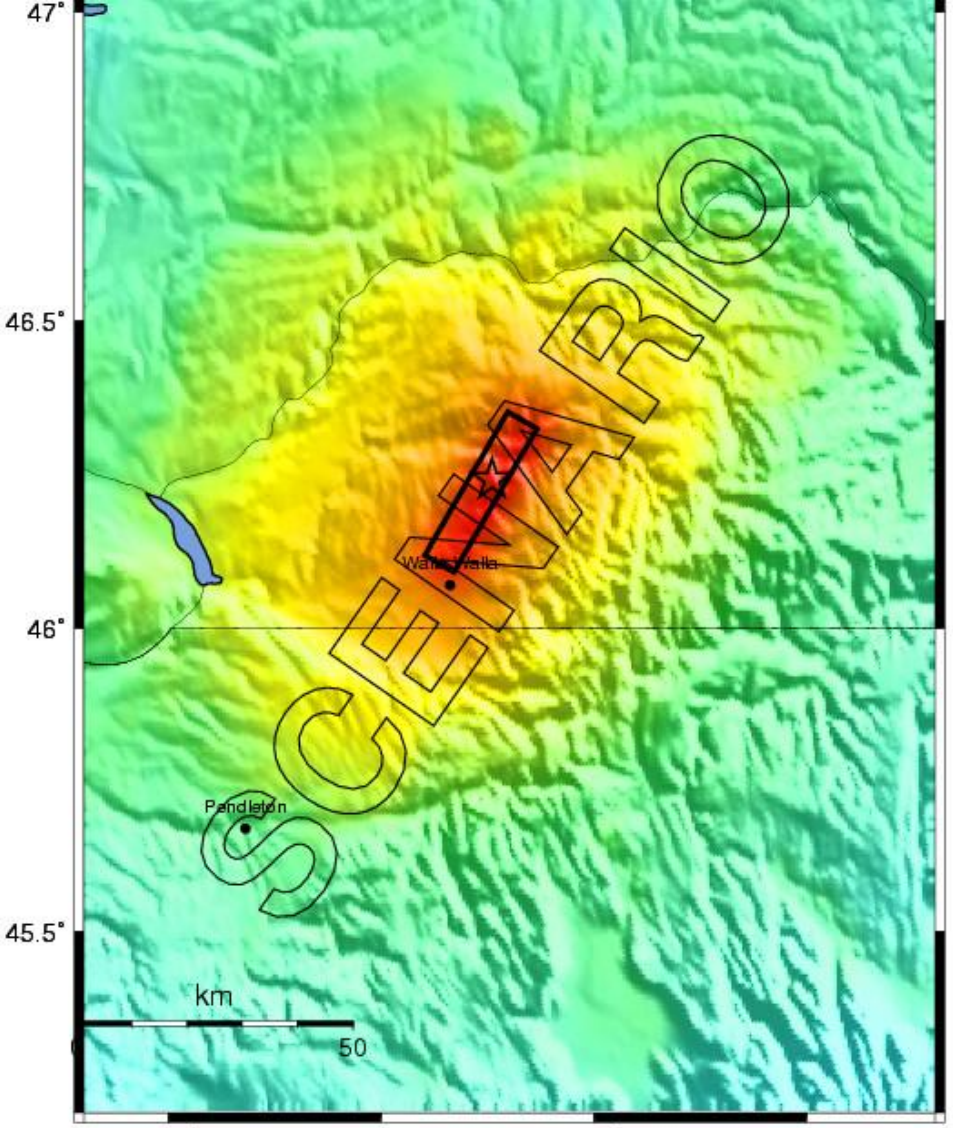
Building Address: Page: 2 of 2

Job Number: Job Name: By: DRW Checked:

ASCE 31 BASIC CHECKLIST URM: UNREINFORCED MASONRY BEARING WALL BUILDINGS WITH FLEXIBLE DIAPHRAGMS

C	NC	N/A			Comments
			BUILDING SYSTEM		
☒	☐	☐	4.3.3.11	UNREINFORCED MASONRY WALL CRACKS: There shall be no existing diagonal cracks in the wall elements greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, or out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, and shall not form an X pattern.	
			LATERAL-FORCE-RESISTING SYSTEM		
☒	☐	☐	4.4.2.1.1	REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy.	
☐	☐	☒	4.4.2.5.1	SHEAR STRESS CHECK: The shear stress in the unreinforced masonry shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 30 psi for clay units and 70 psi for concrete units for Life Safety and Immediate Occupancy.	**Not evaluated due to retrofit with SCBF's.**
			CONNECTIONS		
☐	☒	☐	4.6.1.1	WALL ANCHORAGE: Exterior concrete or masonry walls, that are dependent on the diaphragm for lateral support, shall be anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections shall have adequate strength to resist the connection force calculated in the Quick Check Procedure of Section 3.5.3.7.	**See details 4 and 5 on Sheet S5.2**
☒	☐	☐	4.6.1.2	WOOD LEDGERS: The connection between the wall panels and the diaphragm shall not induce cross-grain bending or tension in the wood ledgers.	**See details 4 and 5 on Sheet S5.2**
☒	☐	☐	4.6.2.1	TRANSFER TO SHEAR WALLS: Diaphragms shall be connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the lesser of the shear strength of the walls or diaphragms for Immediate Occupancy.	
☐	☐	☒	4.6.4.1	GIRDER/COLUMN CONNECTION: There shall be a positive connection utilizing plates, connection hardware, or straps between the girder and the column support.	**Floor joists span between bearing walls only.**

Scenario Magnitude 6.7 earthquake on the Hite fault, scaled up from the 1936 Milton-Freewater earthquake (from Art Frankel)



PLANNING SCENARIO ONLY -- Map Version 2 Processed Wed Aug 4, 2010 04:57:21 PM MDT

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

WASHINGTON STATE DEPARTMENT OF Natural Resources

Walla Walla, Building Code Value

Name	None	Slight	Moderate	Extensive	Complete	At least extensive
BERNEY ELEM	53%	22%	20%	4%	1%	5%
BERNEY ELEM GYM	53%	22%	20%	4%	1%	5%
BLUE RIDGE ELEM	62%	24%	12%	2%	0%	2%
EDISON ELEM	61%	20%	16%	3%	0%	3%
GARRISON MIDDLE S	64%	26%	9%	1%	0%	1%
GREEN PRK ELEM_additional	64%	26%	9%	1%	0%	1%
GREEN PRK ELEM_original	39%	26%	24%	9%	2%	11%
LINCOLN ALTERNTV HS	39%	26%	24%	9%	2%	11%
PAINE CAMPUS	62%	27%	10%	1%	0%	1%
PIONEER MIDDLE	64%	26%	9%	1%	0%	1%
PROSPECT POINT ELM	29%	15%	31%	22%	3%	25%
SHARPSTEIN (Gym and Lunch)	69%	16%	13%	3%	0%	3%
SHARPSTEIN ELEM S	51%	28%	19%	1%	0%	1%
WALLA WALLA HS (Academic)	61%	18%	17%	4%	0%	4%
WALLA WALLA HS (Auditorium)	42%	26%	28%	4%	0%	4%
WALLA WALLA HS (Commons)	29%	15%	31%	22%	3%	25%
WALLA WALLA HS (Large Gym)	61%	18%	17%	4%	0%	4%
WALLA WALLA HS (Library)	48%	23%	24%	5%	1%	6%
WALLA WALLA HS (Music)	32%	21%	36%	9%	2%	11%
WALLA WALLA HS(Science)	29%	15%	31%	22%	3%	25%
WALLA WALLA HS (Small Gym)	29%	15%	31%	22%	3%	25%
WALLA WALLA HS (Vocational)	48%	23%	24%	5%	1%	6%
WALLA WALLA (Admin Bldg)	54%	32%	13%	1%	0%	1%

Walla Walla, Scenario M6.7 earthquake

Name	None	Slight	Moderate	Extensive	Complete	At least extensive
BERNEY ELEMENTARY	0%	2%	24%	59%	15%	74%
BERNEY ELEMENTARY (Gymnasium)	0%	3%	31%	56%	10%	67%
BLUE RIDGE ELEMENTARY	0%	4%	39%	49%	8%	56%
EDISON ELEMENTARY	52%	38%	10%	0%	0%	0%
GARRISON MIDDLE	34%	54%	12%	0%	0%	0%
GREEN PARK ELEMENTARY L (addition)	2%	24%	66%	9%	0%	9%
GREEN PARK ELEMENTARY (original)	1%	14%	51%	30%	4%	34%
LINCOLN ALTERNATIVE HIGH	3%	19%	53%	23%	3%	26%
PAINE CAMPUS	0%	16%	26%	29%	28%	57%
PIONEER MIDDLE	28%	56%	16%	0%	0%	0%
PROSPECT POINT ELEMENTARY	48%	33%	19%	1%	0%	1%
SHARPSTEIN ELEM S (Gym and Lunch)	42%	34%	23%	1%	0%	1%
SHARPSTEIN ELEMENTARY	4%	21%	66%	10%	0%	10%
WALLA WALLA HS (Academic)	54%	30%	15%	1%	0%	1%
WALLA WALLA HS (Auditorium)	21%	37%	40%	2%	0%	2%
WALLA WALLA HS (Commons)	7%	30%	50%	13%	1%	14%
WALLA WALLA HS (Large Gym)	54%	30%	15%	1%	0%	1%
WALLA WALLA HS (Library)	27%	36%	35%	2%	0%	2%
WALLA WALLA HS (Music)	21%	37%	40%	2%	0%	2%
WALLA WALLA HS (Science)	54%	30%	15%	1%	0%	1%
WALLA WALLA HS (Small Gym)	7%	30%	50%	13%	1%	14%
WALLA WALLA HS (Vocational)	27%	36%	35%	2%	0%	2%
WALLA WALLA ADMIN BUILD.	28%	56%	16%	0%	0%	0%

In subsequent years, we hope to be able to secure dedicated funding to extend this analysis statewide or at least to school districts prioritized on the basis of this analysis. Alternatively, school districts could be prioritized in order of the amount by which ground shaking hazard has increased in the current building code since enactment of the State Building Code Act of 1974. Based upon the results of this pilot project it is estimated that completing a statewide assessment program using the previously described approach would be roughly $10-13 million dollars that could be phased over an 8-10 year period. This equates to approximately $3,500-$4,500 per public school throughout the state and such an approach could be supported by a combination of federal, state, and local resources.

Table 3. School retrofit projects in Washington since the Nisqually earthquake, February 28, 2001. The total is the total cost of the project, including FEMA, state and local matching funds.

Project	Cost	Status
Retrofit of Residence Hall A at The Evergreen State College	$1,456,463	Ongoing
Retrofit of Library Clock Tower at The Evergreen State College	$1,055,600	Ongoing
Non-structural retrofit at Burke Museum at the University of Washington	$949,039	Nearing completion
Retrofits of two dormitories at Pacific Lutheran University	$2,100,334	Complete
Retrofits of two dormitories at Pacific Lutheran University	$2,100,334	Complete
Retrofit shop at Lake Washington Technical College	$72,163	Complete
Retrofit of nine elementary schools in Edmonds	$6,966,715	Complete
Retrofit of facilities at Clark College in Vancouver	$1,359,915	Complete
Retrofit of facilities at Clark College in Vancouver	$1,359,915	Complete
Retrofit of school auditorium/cafeteria in LaConner	$702,658	Complete
Retrofit of elementary school in Littlerock	$875,535	Complete
Retrofit of Roy Elementary School near Tacoma	$555,172	Complete
Total	**$18,998,671**	

Seismic retrofits of Washington schools since the Nisqually earthquake funded at least in part by FEMA. This methodology provides enough information to support benefit-cost analysis necessary for grant funding as well as nonstructural mitigation that could be part of normal maintenance. We are in discussions with OSPI to develop innovative funding options.